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Investigating Use of Space and Human-Animal Interactions in Agricultural Built Environments: The Geo-ethnoarchaeology of Livestock Dung

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Abstract

Livestock dung is a valuable ubiquitous material within built environments as it embeds critical information on a range of environmental and ecological issues and socio-economic and cultural life-ways. Dung, however, is regularly overlooked, due in part to methodological challenges in its identification and to research frameworks. This paper reviews the contribution of integrated analytical techniques in geoarchaeology and archaeobotany to interdisciplinary approaches and debates on the identification of dung. Geo-ethnoarchaeological and experimental approaches provide comparative datasets and models on factors affecting dung formation and preservation, and the natural and anthropogenic pathways influencing these. A selection of geo-ethnoarchaeological case-studies are presented here from the Near East, one of the key heartlands in which plants and animals that were domesticated occur naturally, and from northern Africa, a potentially critical area in the development of agriculture with implications for surrounding regions including the Mediterranean and the Sahara. These case-studies demonstrate the value of much needed interdisciplinary studies of livestock dung for delineating human-animal interactions, use of living spaces and energy sources, with particular focus on early food-producing communities and the development of farming systems.

1. Introduction

There is growing recognition of the fundamental importance of the built environment in shaping lives and livelihoods, as well as the value of interdisciplinary approaches to studies of ecological and socio-cultural practices. Recent interdisciplinary research has highlighted the prevalence of livestock dung in many settlements, and ways in which it can provide key information on environment, plant and animal management, energy sources, socio-economic relations and cultural practices (Shahack-Gross 2011, and references therein). However, this ubiquitous material in many settlements ever since the domestication of herds, is regularly overlooked or missed using conventional excavation procedures, despite its worldwide economic importance as a source of fertilizer, tempering and fuel. As a result, the potential of this data-set has not been fully realized in the archaeological literature and particularly in syntheses on the emergence of early farming systems.

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This paper examines much-needed holistic interdisciplinary sampling strategies and analytical techniques for geo-ethnoarchaeological studies of livestock dung within built environments. It highlights the value of interdisciplinary analytical methods in geoarchaeology and archaeobotany and comparative geo-ethnoarchaeological data to enable a robust identification and interpretation of dung remains. The focus here is on calcitic dung spherulites that originate in the digestive tracts of many animal species, opal phytoliths, and micromorphology. The strength of this integrated micro-contextual approach lies in its ability to examine these micro-fossils and indicators in the archaeological record within their depositional and socio-economic context in built environments. Comparative geo-ethnoarchaeological research provides an important framework for examining the significance of these indicators and their contextual associations, as highlighted in a review by Friesem (2016). Geo-ethnoarchaeology is used in the research reported on here, to provide comparative reference models and analytical data-sets on the characteristics, preservation and context of modern dung materials, dung-products and depositional contexts in current farming communities that maintain some aspects of traditional ways of life. The materials examined include fresh dung pellets, sediments from animal pens, dung cakes, dung fuel from ovens, and building materials. The specific objectives in research on this comparative data are, first, to obtain information on variation in the digestibility, durability and seasonality of phytoliths and other microfossils that are excreted with dung, which are still under-developed, to inform on their representation in settlement deposits. Second, to illustrate the potential major contribution of dung in tracing interactions between humans and animals within built environments, and particularly the various ways that these built environments were organized and their socio-economic implications, a selection of case-studies are examined from around the 9th-8th millennium cal BC. These case-studies are primarily from the northern Levant and central Anatolia, two core regions in the spread of farming, with comparative ethnoarchaeological reference to the Eastern Maghreb.

2. Case-studies and archaeological implications

2.1. Research areas, materials and methods

This paper brings together data from geo-ethnoarchaeological studies conducted in the Upper Khabur (northeastern Syria), the Konya plain in central Anatolia (Turkey), and the High Tell in northwestern Tunisia (Portillo *et al.* 2012; 2014; 2017; Anderson and Ertuğ -Yaraş 1998). This geo-ethnoarchaeological data has been then used as comparative reference material in integrated geoarchaeological studies of a number of nearby Prehistoric and Protohistoric settlements in these regions: early Neolithic Tell Seker Al-Aheimar in Syria (8th–7th millennium cal BC); early Neolithic Boncuklu (9th–8th millennium cal BC), Pınarbaşı (7th millennium cal BC) and Çatalhöyük (8th–6th millennium cal BC) in central Turkey; and Iron Age Althiburos in Tunisia (1st millennium BC) (Portillo and Albert 2011, 2016; Portillo *et al.* 2012; 2014; 2017; 2019; Matthews and Portillo 2017; García-Suárez *et al.* 2018). Ethnographic research was conducted in rural villages with full permissions following ethical protocols, in a range of local communities in which traditional non-mechanized husbandry practices are still common and animal dung is used in many ways, primarily as fertilizer, fuel and occasionally construction material in threshing floors and roofing. Field work included informal interviews and ethnographic observations on dung production, management, and storage, waste disposal, and traditional means of manuring, building and cooking in mud near eastern *tannur* and Tunisian *tabouna* ovens, as well as the collection of modern reference materials. The sampled materials and activity areas included: fresh dung pellets, sediments from pens, agricultural fields and pasture grounds, dung cakes, dung fuel residues from ovens and building materials, such as mud bricks and roofing.

Through synthesis of recent ethnoarchaeological research in early Neolithic Tell Seker Al-Aheimar and Numidian Althiburos (Portillo *et al.* 2012; 2014; 2017), and new reference data from central Anatolia that builds on Anderson and Ertuğ-Yaraş's (1998) ethnobotanical work on dung fuel use in rural settlements on the edge of the Taurus Mountains, we emphasize the value of geo-ethnoarchaeological approaches using a range of analytical methods in geoarchaeology and archaeobotany, such as dung spherulites analyses and plant microfossil evidence (phytoliths and calcitic wood ash pseudomorphs, resulting from the heating of calcium oxalate crystals commonly produced by dicotyledonous matter) in combination with contextual micromorphology to enable more robust identification and interpretation of dung content and context within built environments. Table 1 summarizes the various methods used in this research.

2.2. Animal dung, faecal deposits and activity areas

Fresh herbivore dung pellets are usually porous, loosely packed and consist mainly of poorly digested to undigested plant remains, which are sometimes embedded in a brown to dark brown amorphous organic groundmass (Brönnimann *et al.* 2017). On the basis of plant fragment size and texture, it is possible to distinguish between cattle, ovicaprines, horses and herbivorous pigs, which are the most common faecal remains in archaeological contexts. According to observations in micromorphological thin sections from reference experimental and ethnoarchaeological materials (Fig. 1a–b), fresh herbivorous excrements may display distinctive poorly digested to undigested plant tissues and seeds, and plant microfossils such as phytoliths and calcium oxalates, cellulose showing interference colors under crossed polarized transmitted light (XPL), amorphous organic matter, and organic phosphate staining, normally pale to dark brown under plane light (PPL), and other distinctive faecal features such as calcitic dung spherulites and coprofilous spores, although their composition may vary significantly according to species and diet. Once deposited within an enclosure, fresh organic materials become trampled and compacted by the animals, resulting over time in a laminar structure with elongated plant tissues oriented sub-parallel to the surface (or stable floor) resulting in a microlaminated deposit, in cases of grass-dominated diets (Macphail *et al.* 2004: Fig. 1b).

The reported geo-ethnoarchaeological studies were conducted in three small villages from the Upper Khabur (modern Seker al-Aheimar, Syria) and the High Tunisian Tell (Guasdya and El Souidat). Ethnoarchaeological observations are detailed in Portillo *et al.* (2012; 2014; 2017) and followed the same methodological microanalytical approach regarding dung content execrated by different animal producers, based in integrated analyses of plant and faecal microfossils, primarily phytoliths and dung spherulites. These are expressed in estimations of number of microfossils per gram of material, sediment and/or acid insoluble material resistant to chemical attack (AIF % in Table 2), proportions of phytoliths that were unidentifiable due to the surface pitting and etching caused by dissolution (weathering %), and multicellular structures (multi-celled or interconnected phytoliths). Table 2 also lists sample provenance, including information on animal producers– mainly ruminants with additional comparative datasets from omnivorous pigs, dogs, hen and rodents, location corresponding to a variety of ecologies, environments, and management practices, and known diet as recorded through the ethnographic fieldwork.

All samples relate to summer phytolith-rich grass diet and showed high concentrations of these and dung spherulites, especially among herbivorous samples. Surprisingly, there was little differentiation in their dietary preferences/choices or grazing environment, as all dung pellets yielded similar phytolith assemblages dominated by grasses from the Pooideae subfamily. Multi-celled or anatomical connected phytoliths, mostly from leaves/ stems, but also from floral parts, were noted in similar proportions among the samples. By contrast, multicelled phytoliths were almost absent in the pig dung pellet from a non-commercial farm in northeastern Spain outside the study-area and related to a diet based on cereal industrial fodder which may disaggregate these into single phytolith cells. Ongoing experimental studies are exploring whether this may be due also to a possible differential digestive process of these animals. The results indicated exceptionally high spherulite concentrations in dung pellets from sheep/goat and cattle, supporting previous studies which show that dung spherulites are mostly produced by ruminants (Canti 1999). The only sample in which spherulites were not observed is the rodent faeces (house mouse) collected from an open-air storage area. More systematic research, however, is needed to evaluate aspects of digestibility and preservation of phytoliths and other remains in order to establish the range of differences between particular herbivorous and omnivore species. Most of the ethnoarchaeological sediment samples from soils in agricultural fields and pasture grounds, livestock pens, and a range of household activity areas and building materials, yielded high phytolith concentrations. In contrast, spherulites counts were low, especially when compared to fresh dung pellets obtained from the same animal producers. Further studies are needed to establish whether this is due to diagenesis.

As previously advocated, these ethnoarchaeological datasets have been compared to geoarchaeological studies from the nearby archeological sites, early Neolithic Tell Seker Al-Aheimar in Syria (Portillo *et al.* 2014) and Numidian Althiburos in Tunisia (Portillo and Albert 2011; 2016; Portillo *et al.* 2012; 2017). The overall aim was to improve the interpretation of living spaces and energy sources and to understand the development of farming communities in these regions. The relation between phytoliths and spherulite content, established in these and other ethnographic and experimental studies, informed interpretations of the nature of the vegetal and faecal matter deposited in living spaces and whether they represent agricultural products and by-products, such as crop storage, fodder, animal dung and dung-products including mixed fuel remains from hearths and ovens. The household debris identified included crop-processing remains, building materials, and fuel residues composed of mixture of dung and plants, reported below.

2.3. Dung fuel and fire installations

Fire-related studies of fuel remains and fire installations such as hearths and ovens have been proven as powerful avenues for investigating the ecological and social significance of many aspects of human life-ways, including the relationships between fire use and environment, energy supply and pyrogenic activity, as well as social relations and cultural behaviors. A wide range of analytical techniques including ethnoarchaeological approaches from the field of geosciences have been directed to investigate the nature of fuel supply, energy production, fire use and fire-related social and cultural behaviours within built environments (Weiner 2010, and references therein). In particular, microanalytical techniques enable simultaneous studies of diverse organic, inorganic and microartefactual materials *in situ* within their depositional context in micromorphological thin-sections and, thereby permit high-resolution analysis of fire traces and their properties, sequences and associations that are critical for interpreting the archeological record (Matthews 2016). The geo-ethnoarchaeological studies above-reported included examinations of firing installations, two of which focused specifically on dung fuel use and the so-called dung cakes.

The first geo-ethnographic case-study is from continued research in rural High Tunisian Tell (village of El Souidat), inhabited by families from the *Ouarten* tribe that subsist on farming mostly of sheep and goats, in addition to cereal agriculture, where livestock is the main source of fuel at the present day. This research followed a similar methodological approach to investigate the associations between plant microfossils (phytoliths and calcitic wood ash pseudomorphs) and calcitic spherulite contents in dung fuels (Portillo *et al.* 2017). It focused on ethnographic observations on dung production and drying in open spaces, management, and storage in specific facilities (namely *Kamur*), waste disposal and manuring with fuel ashes in household gardens, as well as traditional means of cooking in *tabouna* ovens. It included time measurements from the initial fire lighting and the end of cooking and temperature measurements using a portable thermometer with two detectors: one was placed within the burning fuel at the bottom (ovicaprine dung), and the second as close as possible to the oven's wall in order to record the cooking temperature (see Fig. 4 in Portillo *et al.* 2017: 136). These enabled measurement of temperatures within the oven over time, recording a rapid increase in temperature (up to 800ºC in a few minutes) and 30 minutes later temperatures around 100–120ºC within the oven wall during the 5 minutes cooking activity consisting in the baking of twelve bread cakes or *Khobz*. Fuel at the oven-base was *c.* 200ºC about 2 hours later. This data is consistent with experiments conducted in rural Uzbekistan by Gur-Arieh and colleagues (2013), as well as with previous baking measurements in near eastern *tannur* ovens in the Upper Khabur, where the main fuel source is woody matter from cotton production, while ovicaprine dung is only residually used (Portillo *et al.* 2014).

All of these ethnoarchaeological experiments have provided direct microfossil evidence for distinguishing between dung-dominated and wood-dominated fuels in the archeological record (Table 3). Here again there is little difference in the phytolith assemblages which are all dominated by grasses, and spherulite concentrations were extremely abundant in dung-dominated samples. Regarding the morphologic results, most of the phytoliths related to a livestock grass-rich diet from agricultural by-products, including wheat and barley. Most were well-preserved with 10–30% in anatomical connection, but a higher dissolution degree in fuel ashes. Evidence of melting in phytoliths was also observed, altering morphologies due to high temperatures, noted in firing measurements at around 800 ºC. These findings allowed the distinction between wood *versus* dung-dominated materials at nearby Numidian Althiburos, and were supported by evidence from wood ash pseudomorphs, derived from calcium oxalates heating to at least 450ºC, following the methods of Gur-Arieh *et al.* (2013) based on the calculation of the ratio of ash pseudomorphs to dung spherulites. This methodological approach was also applied to interpret Levantine Iron Age cooking installations (Gur-Arieh *et al.* 2014) and therefore has significantly improved the ability of geoarchaeologists to identify the type of fuel used in archaeological contexts (Friesem 2016). This integrated methodology provided direct evidence of the type of fuel sources: wood (likely Aleppo pine); a mixing of vegetal matter (wood and perhaps grass leaves and stems from agricultural by-products, such as barley and wheat) with dung; and dung-dominated matter. Results suggested the use of livestock dung as fuel source at the site from the begging of the fist millennium to the last centuries BC (Portillo *et al*. 2017).

The second case-study reported here focused on pilot phytolith and spherulite results from micromorphological thin sections from dung cakes and fuel ashes from the Konya plain, in central Anatolia. The present study builds on the ethnobotanical research by Anderson and Ertuğ-Yaraş (1998) conducted in the nineties in two small settlements on the edge of the Taurus Mountains, and examines micromorphological thin-sections of samples collected by them. They identified different types of dung cakes or *tezek* (the generic Turkish name for dung): unprocessed droppings collected from the ground, compacted dung from pens, cattle dung moulded by hand into a round (namely *yapma*), and cattle dung compressed into a wooden mould (called *kepiç)*. Preparation was carried out primarily in spring and summer. Burning installations included the so-called *tandir*, a ventilated underground oven similar to modern *tannurs* and *tabounas* used for cooking. The main source of fuel was compacted sheep and cattle *tezek* cakes (Fig. 1b). Both phytoliths and spherulites numbers were examined in thin sections in 20 fields of view at 200× and 400× (Table 4). All phytolith assemblages were dominated by grasses, independently of the season of collection. As expected, the proportion of multicelled phytoliths, mostly derived from grass leaves and stems, was particularly high (up to around 60% of the total counted) in comparison to chemically extracted samples above reported in previous case-studies (Table 3). This may be in most part due to differential sampling and extraction protocols (acid extraction that may fragment phytolith size *versus* thin section), as pointed out in previous experimental studies on multicelled phytolith preservation (Jenkins 2009; Shillito 2011). Here again we noted differences among spherulite concentrations according to the type of dung material: non-treated sheep stored dung, cattle dung cakes and mixed fuel ashes, with lower amounts in the latter group of samples. The presence of melted phytoliths in association with calcitic ashes provided some insights into firing activity, indicating high temperatures, and, notably, were also associated with darkened spherulites which are commonly produced at temperatures between 600–700°C (Canti and Nicosia 2018). Interestingly, the phytolith morphological study revealed differences between samples that could be related to animal diet and foddering and grazing patterns, as well as to seasonality. Although all samples were dominated by grass leaves and stems, differential proportions were noted in the phytoliths from grass floral parts in sheep dung collected in different seasons (winter and summer, Fig. 1 d–e). Dung from the summer season included large amounts of multicelled phytoliths from the husks of cereals. These are consistent with the ethnographic observations and macrobotanical assemblages by Anderson and Ertuğ-Yaraş (1998) relating to a summer-rich diet in which a number of grains from several cereals were identified (wheat, barley, rye and oat) in addition to wild/weed seeds. However, as the authors caution, differences between dung types may be difficult to assess in the archaeological record, due to variation in selection of feed by both animals and humans. Dung from different seasons, animals, husbandry regimes, may be collected and stored for a long time – up to several years, and material not present in the dung itself may be included in the manufacturing process of dung cakes or firing lighting (such as reeds). Key indicators of these variables are being investigated in ongoing integrated studies.

These comparative geo-ethnoarchaeological datasets have been recently used in order to inform interpretations of cooking installations and dung fuel remains from open areas in a selection of contexts from key sites in the Konya plain spanning from 9th-6th millennium cal BC, including early Neolithic Boncuklu, Pınarbaşı, and Çatalhöyük, and are being compared to biomolecular data from Gas Chromatography Mass Spectroscopy (GC-MS) to identify the faecal matter producers (García-Suárez *et al.* 2018). Integrated micromorphological and microfossil observations and comparison with this geo-ethnoarchaeological data, have contributed to the investigation of formation processes in all three early Neolithic settlements, illustrating the variability of dung deposits found in open spaces, dung fuel exploitation, and the complexity of interactions between humans and animals in this key region through time.

3. Conclusions

The integration of analytical methods from geosciences such as micromorphology and microfossil analyses to ethnoarchaeological comparative datasets of livestock dung in the studies reported highlights the usefulness of building up interpretative frameworks of reference for tracing the interactions and relations between humans and animals within built environments. In summary, these integrated approaches have illustrated the potential contribution of the still much-needed systematic interdisciplinary studies of experimental and ethnographic dung to provide comparative robust data for the development of models for the identification and interpretation of dung remains in archaeology.

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Method	Application
Phytolith extraction (Albert *et al*. 1999, Katz *et al*. 2010)	Determines amount of phytoliths per gram of material/AIF/sediment. May allow identification of different plant/part types and animal diet. By themselves cannot be related to dung; similar phytoliths may derive from dung and non-dung sources. May contribute to reconstruct animal ecology, environment, seasonality as well as foddering and grazing activity and land use.
Dung spherulite extraction (Canti 1999)	Determines amount of spherulites per gram of material/sediment. Serves as an indicator for dung, although absence may be due to dissolution or calcination.
Ash pseudomorph extraction (Gur-Arieh *et al*. 2013)	Determines amount of ash pseudomorphs per gram of ashed material/sediment. Their abundances may indicate a diet that is either based or includes a component of dicotyledonous matter, although they do not have a clear taxonomic value. Ratios ash pseudomorphs/dung spherulites may allow distinction between wood-dominated *vs* dung-dominated fuel.
Contextual micromorphology thin section (Courty 1992, Macphail and Goldberg 2010)	Allows examination of microfossils and other remains *in situ* and determines their associations (i.e. herbivore *vs* omnivore dung); may preserve the original size of multicelled phytoliths; supports diet reconstruction, although accurate identification of microfossils is hampered by thickness of the thin section (~30 µm); may be extrapolated to reconstruct grazing grounds, environment and land use. Identifies the specific depositional context (i.e. microlaminated structure, trampling within an enclosure); helps understand taphonomic processes (i.e. bioturbation, dissolution).

Tab. 1: A summary of the methods used in the selected microfossil case-studies of modern dung (based on Shahack-Gross 2011and personal observations)

Sample num.	Sample description and location	Known animal's diet	Prov.	AIF (%)	Phytoliths 1 g of AIF (million)	Grass phytoliths (%)	Phytoliths weathering (%)	Multicelled phytoliths (%)	Spherulites 1 g of material (million)
D1	Cattle dung from wheat field	Grass, wheat, weeds	SY	66.9	133	89.8	6.9	18.1	145
D2	Cattle dung from fields *ca*. river	Grass, barley, weeds, dicot.	TU	42.3	97	85.8	7.5	12.4	446
D3	Cattle dung from penning	Grass, barley, wheat, weeds	TU	33.1	119	93.5	3.4	18.1	235
D4	Sheep/ goat dung from crop field	Grass, wheat, weeds	SY	63.5	141	91.1	4.8	15.8	249
D5	Sheep/ goat dung from barley field	Grass, barley, weeds	TU	47.6	129	87.1	4.7	15.5	541
D6	Sheep/ goat dung from fields *ca*. river	Grass, barley, weeds, dicot.	TU	42.3	97	85.8	7.5	12.4	446
D7	Sheep/ goat dung from penning	Grass, wheat, weeds, dicot	SY	50.1	145	93.9	2.6	12.3	400
D8	Sheep/ goat from penning	Grass, barley, wheat, weeds	TU	41.1	135.9	91.3	5	32.5	529
D9	Goat dung from fields *ca*. river	Dicot. leaf, fig tree, grass,	TU	33.8	118	84	8.9	17.6	192
D10	Pig dung from penning	Industrial fodder: barley, wheat, rye	SP	28.6	47	97.2	1.3	0.5	6
D11	Dog dung from household	Domestic waste, bread, bones	SY	26.9	8	89.8	3.5	11.8	15
D12	Dog dung from household	Domestic waste, bread	TU	33.5	14	81.3	9.7	10.1	7
D13	Hen dung from corral	Domestic waste, insects	SY	31.1	12	91.9	4.7	13.9	0.05
D14	Mice dung from open storage area	Straw, domestic waste	SY	33.6	1.4	88.3	4.6	17.4	0
S1	Soil from fallow wheat field		SY	60.3	0.46	85.7	7.2	2.8	0.03
S2	Soil from sheep/ goat penning		SY	32.1	10	88.3	5.4	12.4	5
S3	Soil from cattle penning		TU	57.1	49	89.9	5.4	16.9	18
S4	Soil from sheep/ goat penning		TU	47.4	60	82.5	9.4	14.1	12
S5	Soil from poultry corral		SY	40.7	4	83	7.6	7.6	0.1
S6	Soil from straw storage open area		SY	50.6	4	91	2.7	1	0.2
S7	Soil from mud brick preparation area		SY	55.1	1.06	85.2	7.4	4.8	0.01
S8	Mud brick		SY	52	0.63	80.7	7.1	3.7	0.04
S9	Roofing from livestock penning		TU	57.9	20	82.3	10.5	13.8	11

Tab. 2: Description of samples and main phytolith and spherulite results obtained from fresh dung pellets (coded as D), soils, household activity areas, and building materials (S) with indication of provenance (SY: Syria, TU: Tunisia, Spain: SP), known animal diet according to informants, and personal observations (based on Portillo *et al*. 2012; 2014; 2017)

Sample num.	Sample description and location	Prov.	AIF (%)	Phytoliths 1 g of AIF (million)	Grass phytoliths (%)	Phytoliths weathering (%)	Multicelled phytoliths (%)	Spherulites 1 g of material (million)	Ash pseudomorphs 1 g of ashed material (million)	Ratio ash pseudomorphs/ spherulites
F1	Non-burned mixed ovicaprine dung/wood fuel	TU	32	100.6	90.3	4.3	22.3	338	0.15	0.005
F2	Burned sheep/ goat fuel stored in a bin	TU	42	138.1	84.8	9.1	16.7	153	0.59	0.004
F3	Sheep/ goat dung fuel from *tabouna*, upper wall	TU	39.1	62.7	84.6	8.7	14.1	314	0.49	0.002
F4	Sheep/ goat dung fuel from *tabouna*, bottom	TU	37.7	119.3	80.8	12.9	29.5	164	0.95	0.006
F5	Sheep/ goat dung fuel from *tabouna*	TU	39	41	74.9	14.2	15.8	69		
F6	Sheep/ goat burned dung pellet from *tannur*	SY	41.9	41	79.4	12	10.6	0.47		
F7	Mixed wood/sheep/ goat dung fuel from *tannur*	SY	44.1	12	68.7	17.4	14.7	0.07		

Tab. 3: Provenance, description of samples and main phytolith, wood ash pseudomorph and spherulite results obtained from modern dung fuel materials from tabouna and tannur ovens (based on Portillo *et al.* 2012; 2014; 2017)

Sample num.	Sample description and location (after Anderson and Ertug-Yaras 1998)	Season of preparation/ collection	Phytoliths (total num.)	Grass phytoliths (%)	Phytoliths weathering (%)	Multicelled phytoliths (%)	Spherulites (total num.)
F8	Sheep dung *tezek*	summer	212	89.2	2.4	51.9	1628
F9	Sheep dung *tezek*	winter	256	77.4	2.3	52.3	1337
F10	Cow dung *yapma* moulded by hand into a round	August/Sept.	194	88	3.1	46.9	682
F11	Cow dung *yapma* moulded by hand into a round	August/Sept.	294	80.1	4.8	46.3	516
F12	Cow dung *kepiç* compressed into a wooden mould	June/July	239	90.8	2.1	42.7	996
F13	Cow/buffalo dung *tezek*		276	91.6	2.2	59.4	1025
F14	Cow/buffalo dung ash		383	92.7	4.4	46.2	641
F15	Cow/sheep mixed dung ash from *tandir* oven		206	81.7	7.8	38.8	772

Tab. 4: Provenance, description of samples and main phytolith and spherulite results obtained from modern dung (tezek) cakes and fuel ashes from central Anatolia, Turkey. Ethnographic observations and macrobotanical results can be found in Anderson and Ertuğ-Yaraş (1998)

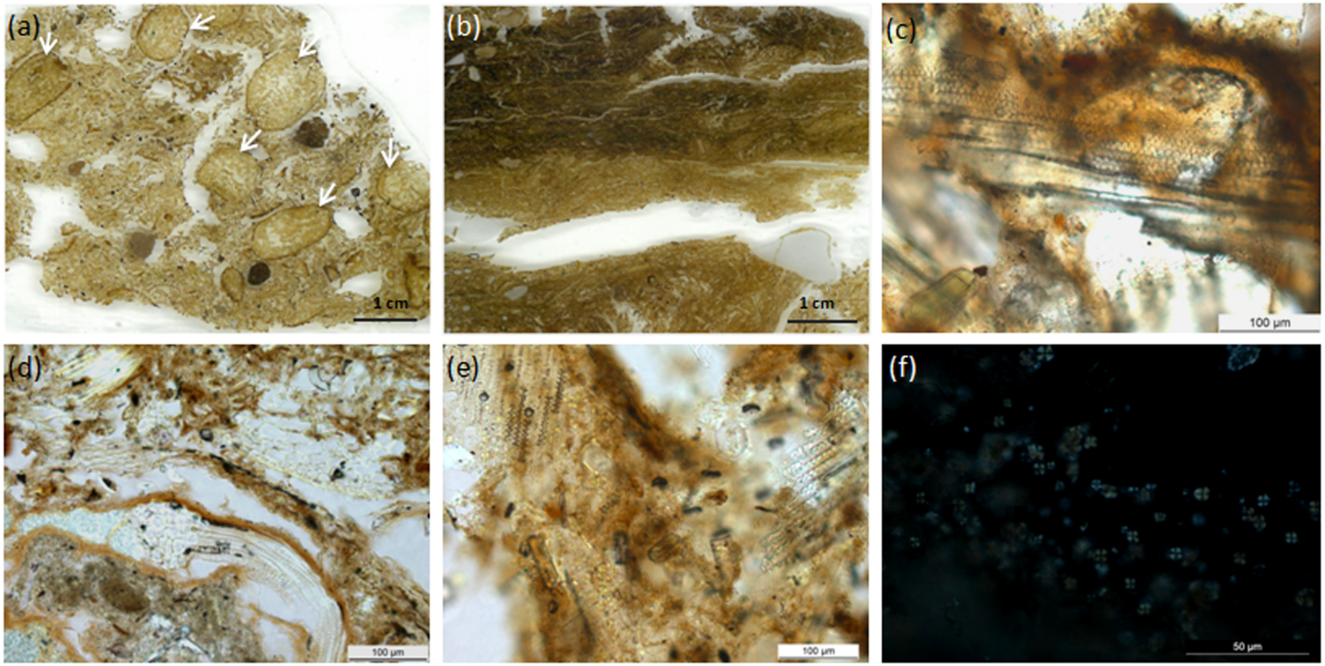

Fig. 1: Modern dung (tezek) cakes and fuel ashes from central Anatolia collected by Anderson and Ertuğ-Yaraş (1998). a) Scan of a resin-impregnated thin section of sheep dung cake containing intact faecal pellets (arrows) and mineral inclusions; b) scan of a thin section of macroscopic laminar structure of compacted trampled dung within a cattle enclosure, where composition is dominated by organic matter but including mineral fragments; c) detail of the same cattle enclosure deposit (image b) showing multicelled or anatomically connected grass phytoliths in a sub-parallel microlaminated structure (photomicrograph taken at 200× under PPL); d) sheep dung cake manufactured in winter displaying multicelled phytolith-rich assemblages of dicotyledonous leaf tissues pointing to a diet that is either based or includes a component of dicotyledonous fodder (200×, PPL); e) sheep dung cake manufactured in summer showing a grass-rich diet composed of multicelled phytoliths from the husks of cereals (200×, PPL); f) calcitic spherulites noted in cattle dung fuel ashes (400×, XPL)